

Search for the Associated Production of Charginos and Neutralinos at the Tevatron

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Abstract. Searches for the associated production of charginos and neutralinos in trilepton final states under the assumption of R-parity conservation have been performed by the CDF and DØ experiments. Both experiments use data taken during Run II of the Fermilab Tevatron $p\bar{p}$ -collider at $\sqrt{s} = 1.96$ TeV, corresponding to integrated luminosities between 220 and 350 pb^{-1} . The data agree with the Standard Model expectation and limits on the production cross section as well as a lower bound on the mass of the lightest chargino are derived, constraining the associated production of charginos and neutralinos beyond previous limits.

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INTRODUCTION

Supersymmetry was introduced as a symmetry between bosons and fermions to solve some of the problems of the Standard Model (SM), e.g. the hierarchy problem and the unification of the gauge couplings of $U(1)$, $SU(2)_L$ and $SU(3)$ [1]. Assuming the conservation of R-parity, a discrete symmetry to distinguish sparticles from ordinary particles: $R_p = (-1)^{3B+L+2S}$, supersymmetric models even provide a candidate for dark matter [2], since the lightest supersymmetric particle (LSP), usually the lightest neutralino, must be stable. Additionally R-parity conservation allows only pairwise creation of sparticles and each sparticle decays into an odd number of sparticles.

All analyses presented here assume $q\bar{q} \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0$ to be the dominant production process. Subsequently the decay $\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow 3\ell + \cancel{E}_T$ provides a clean leptonic signature in contrast to the overwhelming hadronic SM-backgrounds at a $p\bar{p}$ -collider such as the Tevatron. Due to the neutrinos and neutralinos, which escape detection, the final state is also characterized by a significant amount of missing transverse energy.

ANALYSIS STRATEGIES

CDF as well as DØ adopted the strategy to first identify two leading leptons, though with differing requirements on the transverse momentum, p_T , the missing transverse energy, \cancel{E}_T , and different criteria for the invariant mass of the two leading leptons (ee , $\mu\mu$, $e\mu$)

to reduce the background from Z/γ processes, as well as from J/ψ , Υ resonances. At last either a third charged lepton (e , μ) or a third isolated track is required, see Tab. 1. Further details can be found in [3] and in [4] for the CDF and DØ analyses, respectively. Examples of selection cuts are presented in the following Figure 1.

TABLE 1. Overview of the different analyses developed by the CDF and DØ collaborations.

CDF analyses	$p_T^{\ell 1}$	$p_T^{\ell 2}$	$p_T^{\ell 3}$ [GeV]	DØ analyses	$p_T^{\ell 1}$	$p_T^{\ell 2}$	$p_T^{\ell 3}$ [GeV]
$ee\nu_\mu/\mu$ & $\mu\mu\nu_\mu/\mu$	20	8	5	eel & $(e\mu\ell)$	12	8	4 (7)
eel	10	5	4	$\mu\mu\ell$ & $(LS\mu\mu)$	11	5	3 (–)

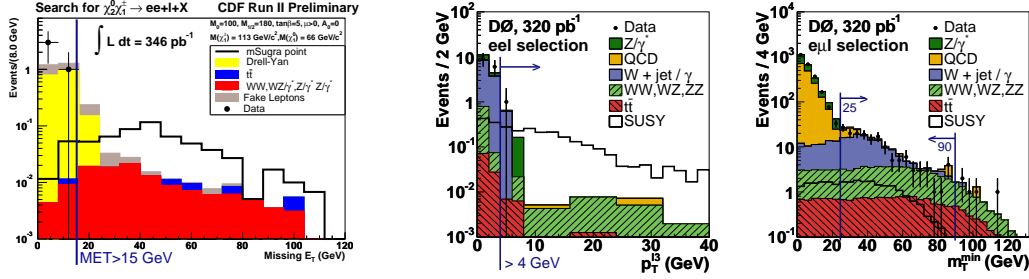


FIGURE 1. The E_T distribution in the CDF $ee\nu_\mu/\mu$ analysis (left), the p_T distribution of a third isolated track in the DØ eel -analysis (middle) and the minimum transverse mass, m_T^{\min} of the electron or muon in the DØ $e\mu\ell$ -analysis (right).

To recover inefficiencies of the triplepton analyses containing electrons and muons DØ has developed two more analyses, focusing on hadronically decaying τ leptons [5]. Due to mixing in the third generation the $\tilde{\tau}$ also becomes the lightest slepton for large values of $\tan\beta$, which results in an increase of the BR into 3 τ 's or 2 τ 's+ e/μ . Since the identification of hadronic τ decays is very difficult, Neural Nets are used to distinguish τ 's from jets of hadronic origin and from electrons. Some of the input variables to the NN are: the shower profile (transverse & longitudinal), the EM-fraction, the isolation (diff. cones: $dR < 0.3 / 0.5$), the reconstructed τ mass and $\frac{p_T(\text{no } \tau\text{-tracks})}{p_T(\text{all tracks})}$.

RESULTS, INTERPRETATION AND PROSPECTS

The results (Tab. 2, Fig. 2(a)) are interpreted either in the framework of mSUGRA [6], where the gaugino masses follow the relation: $M(\tilde{\chi}_1^\pm) \approx M(\tilde{\chi}_2^0) \approx 2 \cdot M(\tilde{\chi}_1^0)$, or in mSUGRA-inspired phenomenological MSSM benchmark models. In the 3ℓ -max scenario with heavy squarks, but light sleptons, the leptonic BR is maximized; the large- m_0 scenario is dominated by gaugino decays via W/Z bosons, which results in small leptonic BR and for the heavy-squarks scenario a relaxed mass unification at the GUT-scale leads to enhanced cross sections for large \tilde{q} -masses.

The numbers of expected signal events and errors for CDF are given for an mSUGRA-point with $M(\tilde{\chi}_1^\pm) = 113$ GeV and $M(\tilde{\chi}_1^0) = 66$ GeV, while the results for the DØ analyses are given for a phenomenological signal point with comparable chargino and neutralino masses: $M(\tilde{\chi}_1^\pm) = 114$ GeV and $M(\tilde{\chi}_2^0) = 114$ GeV. Whereas CDF has not yet set exclusion limits or calculated any mass bounds, DØ has already combined the

six analyses (including those with hadronic τ leptons in the final state). In Fig. 2 (a) the upper limits on the tripleton cross section versus $M(\tilde{\chi}_1^\pm)$ are compared to the cross section curves of three MSSM benchmark models: large- m_0 , 3 ℓ -max and heavy-squarks.

TABLE 2. The number of observed data events, compared to the number of events expected from SM background processes. The errors are statistical and systematic uncertainties added in quadrature.

CDF analyses	N_d	N_{bkg}^{SM}	N_{signal}	DØ analyses	N_d	N_{bkg}^{SM}	N_{signal}
$ee\gamma/\mu$	0	0.17 ± 0.05	0.49 ± 0.06	eel	0	0.21 ± 0.12	2.15 ± 0.18
$\mu\mu\gamma/\mu$	0	0.09 ± 0.03	0.37 ± 0.05	$e\mu\ell$	0	0.31 ± 0.13	1.47 ± 0.13
$ee\ell$	2	0.48 ± 0.07	0.36 ± 0.27	$\mu\mu\ell$	2	1.75 ± 0.57	0.65 ± 0.09
				$LS\mu\mu$	1	0.64 ± 0.38	0.62 ± 0.16
				$e\tau\ell$	0	0.58 ± 0.14	0.41 ± 0.04
				$\mu\tau\ell$	1	0.36 ± 0.13	0.72 ± 0.06
				combined	4	3.85 ± 0.75	6.02 ± 0.30

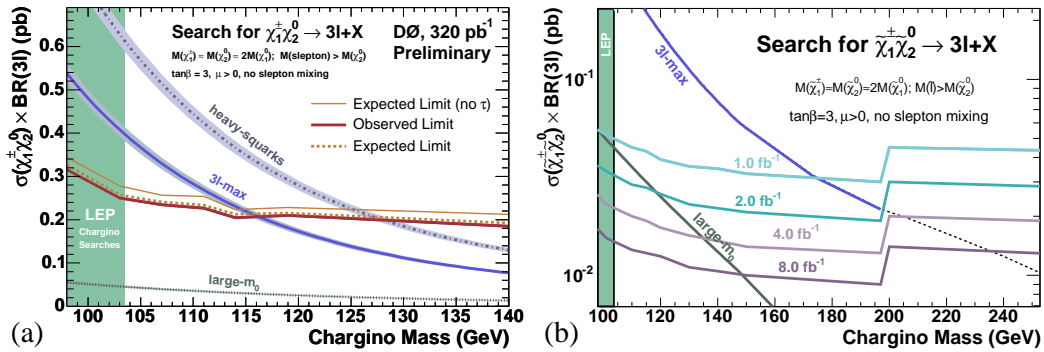


FIGURE 2. (a) Observed and expected upper limits on the tripleton cross section set by the six combined DØ analyses in comparison to the predictions of three MSSM benchmark models: large- m_0 , 3 ℓ -max and heavy-squarks scenario. (b) The CDF and DØ combined expected upper limits on the tripleton cross section for various integrated luminosities and assuming no signal.

In summary, CDF and DØ have searched for tripleton signatures in various channels and observed no deviation from the SM expectation. Upper limits on the SUSY tripleton cross section are derived, and in the 3 ℓ -max scenario a lower bound of 116 GeV on the mass of the lightest chargino is set. Since the sensitivity of the analyses is expected to increase as more data is collected in Run II of the Tevatron, Fig. 2 (b) shows the combined expected limits of CDF and DØ for various integrated luminosities assuming improved analysis techniques and no signal [7].

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